Does ocean color constrain ocean circulation?

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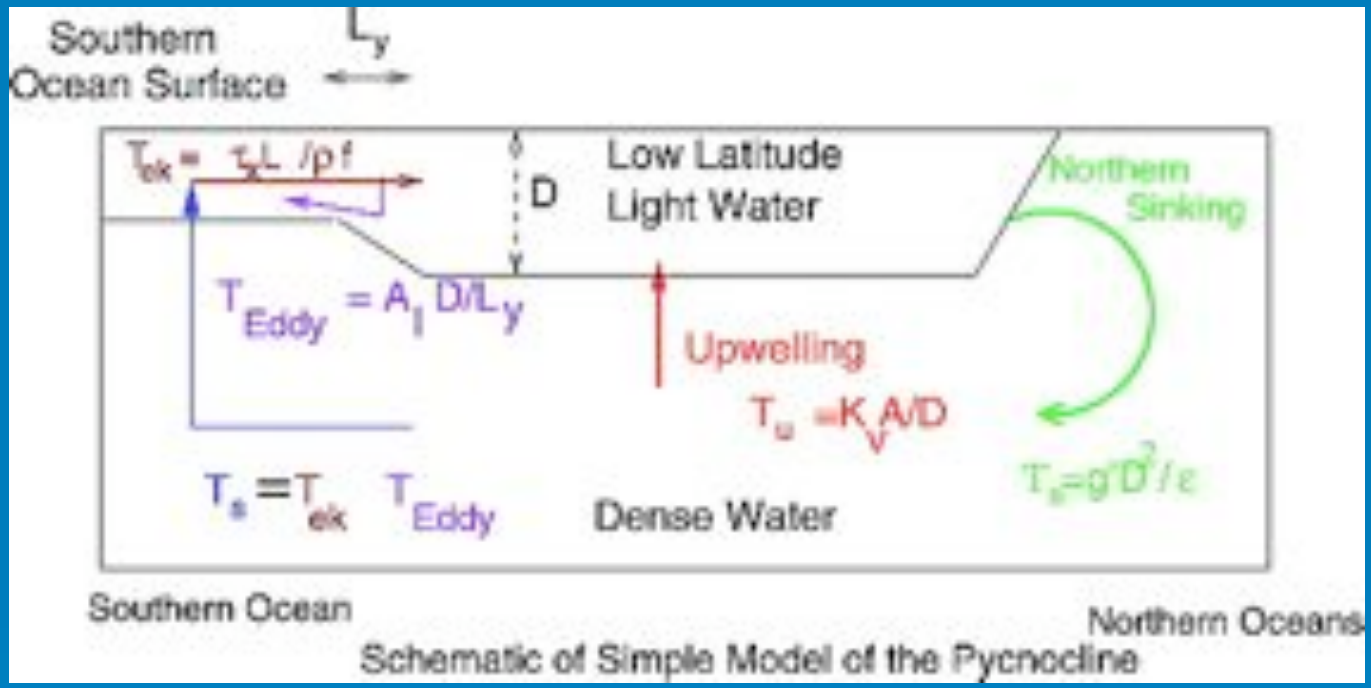
Questions

- Since productivity is controlled by the rate at which nutrients are supplied from below…
- Can estimates of productivity be used to (passively) constrain vertical exchange?

- Since ocean color affects shortwave absorption…
- Does ocean color actively constrain vertical exchange?

Subgridscale mixing and vertical exchange



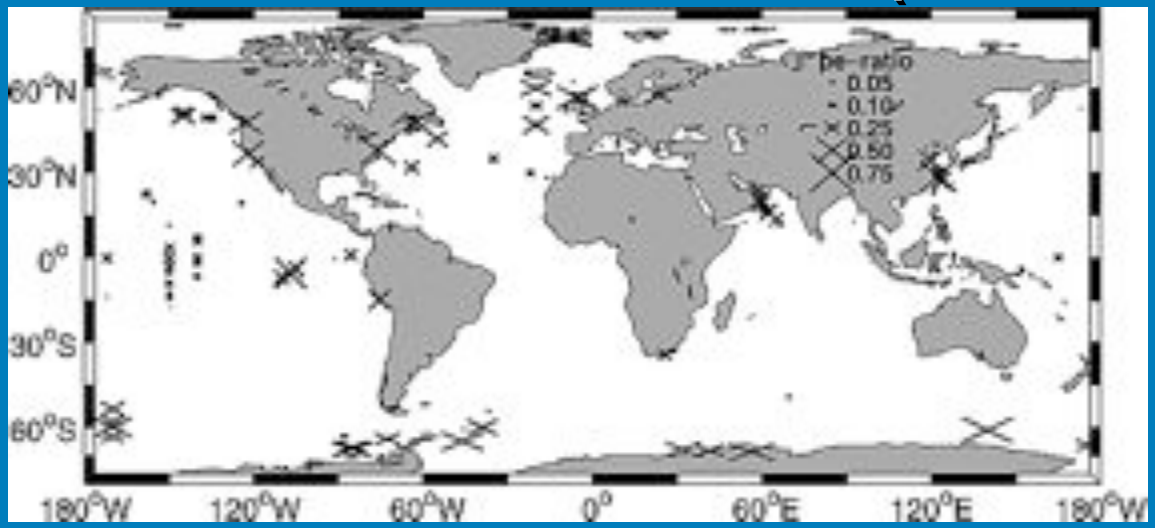
Gnanadesikan (Science, 1999)

High vertical and lateral mixing can supply upwelling from tropics (this is “traditional” conveyor belt. Low mixing, high SO winds offer an alternative.

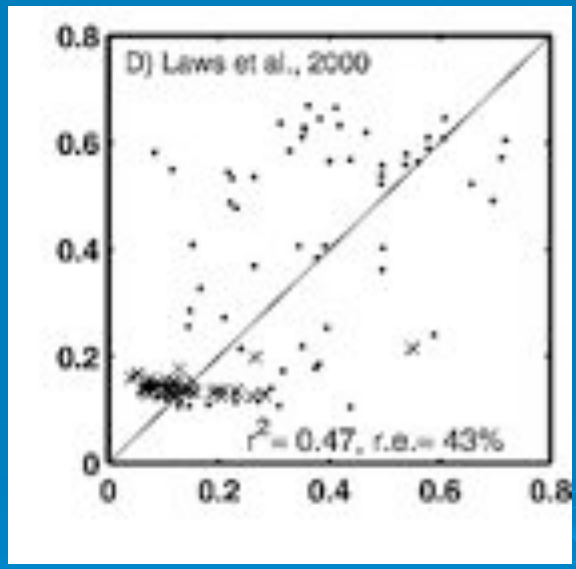
Problem..

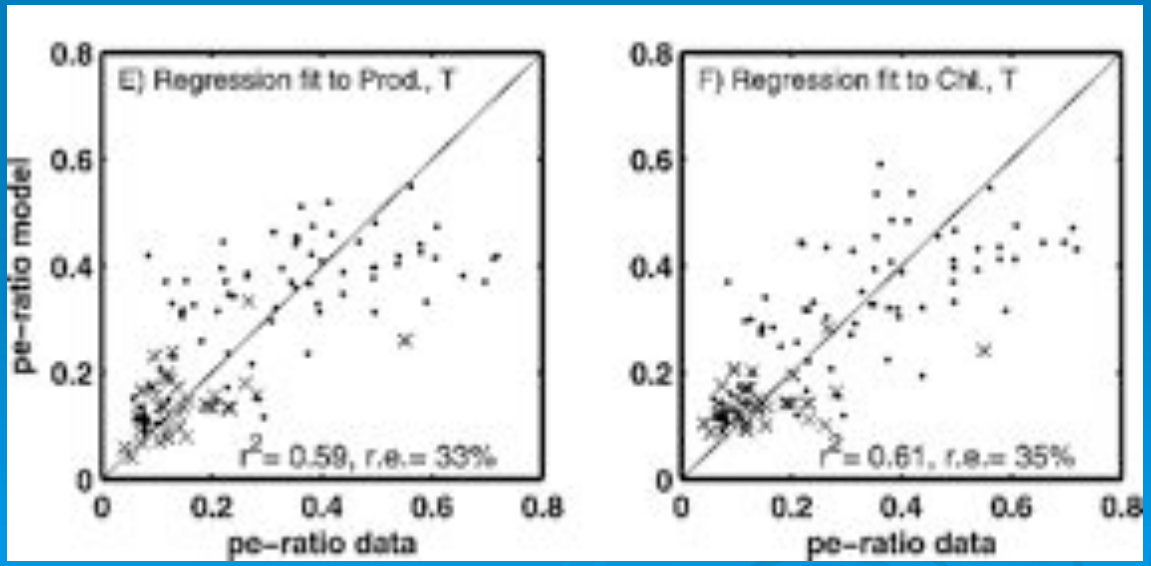
- Diagnostic models estimate what biology has to do to get rid of excess surface nutrients (export production).
- Satellites see primary production.
- Need to link the two.

Dunne et al. (2005), pe-ratio



Estimated at 119 sites around the world.

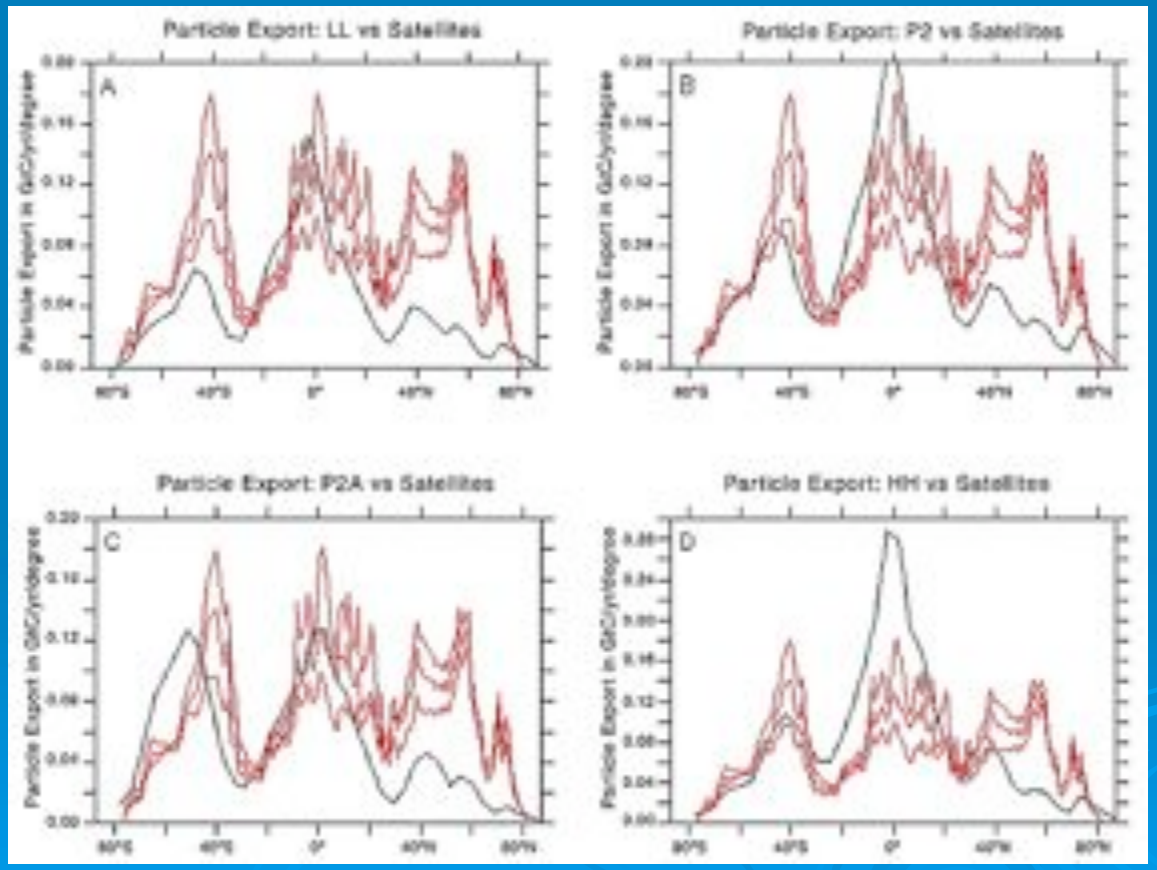




Laws et al. fit is poor because of high tropical values.

Particulate export suggests that high vertical mixing is inconsistent with observed fluxes

… but diagnostic models continue to have significant problems in high latitudes (Gnanadesikan et al.,GBC, 2004).



Overall syntheses

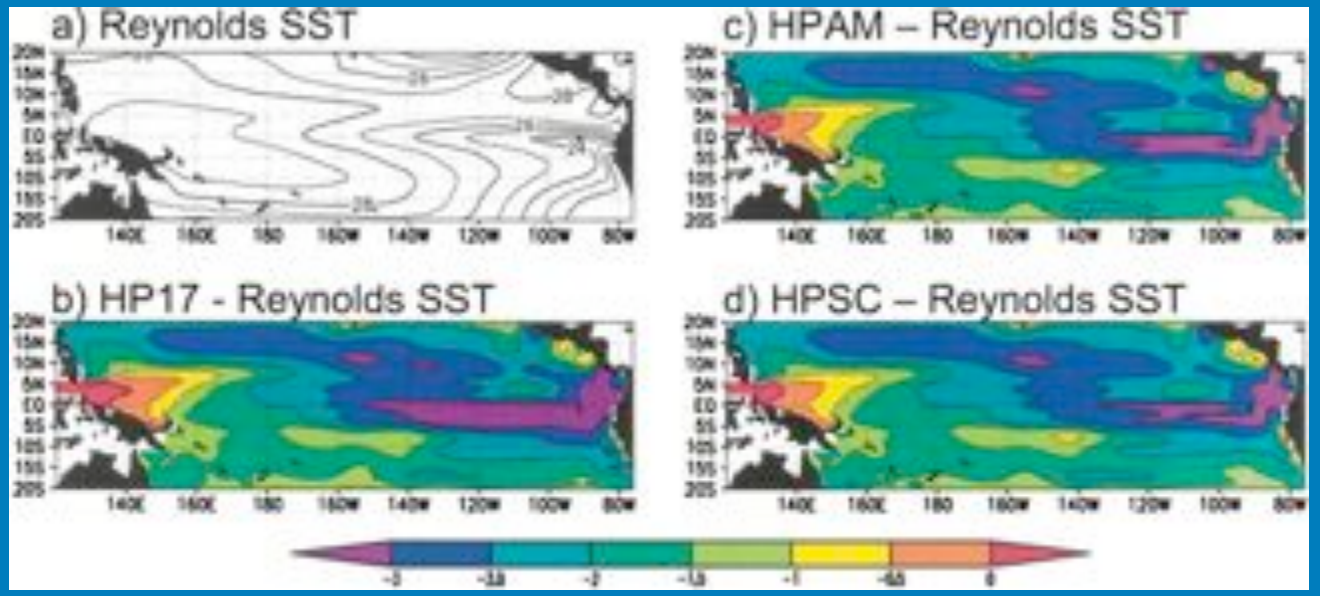
	New estimate	*Models*/data
Global POC export (GtC/yr)	9.6±3.6	11.1-12.9 (Laws et al., 2001) *8.7-10* (*Gnanadesikan et al., 2004*) 9.6 (Schlitzer, 2004)
Global CaCO3 export (GtC/yr)	0.52±0.15	1.1 (Lee et al., 2001) *0.68-0.78* (*Gnanadesikan et al. 2004*) *1.6-1.8* (*Heinze et al., 2003,2004*)
Global Si export (Tmol/yr)	101±35	100-140 (Nelson et al., 1995) *80-90* (*Gnanadesikan, 1999*) *170* (*Heinze et al., 1999*)

Dunne, Sarmiento and Gnanadesikan, accepted GBC

Does ocean color passively constrain vertical exchange?

- To some extent…(general consensus on global particle export ~10GtC/yr)
- …but uncertainties in primary productivity are of the same order of magnitude as differences between models with different subgridscale mixing.

Does plankton concentration directly constrain ocean circulation?



Ballbrera-Poy et al. (2007)- answer would appear to be not very much. But…

No thermodynamic feedbacks.

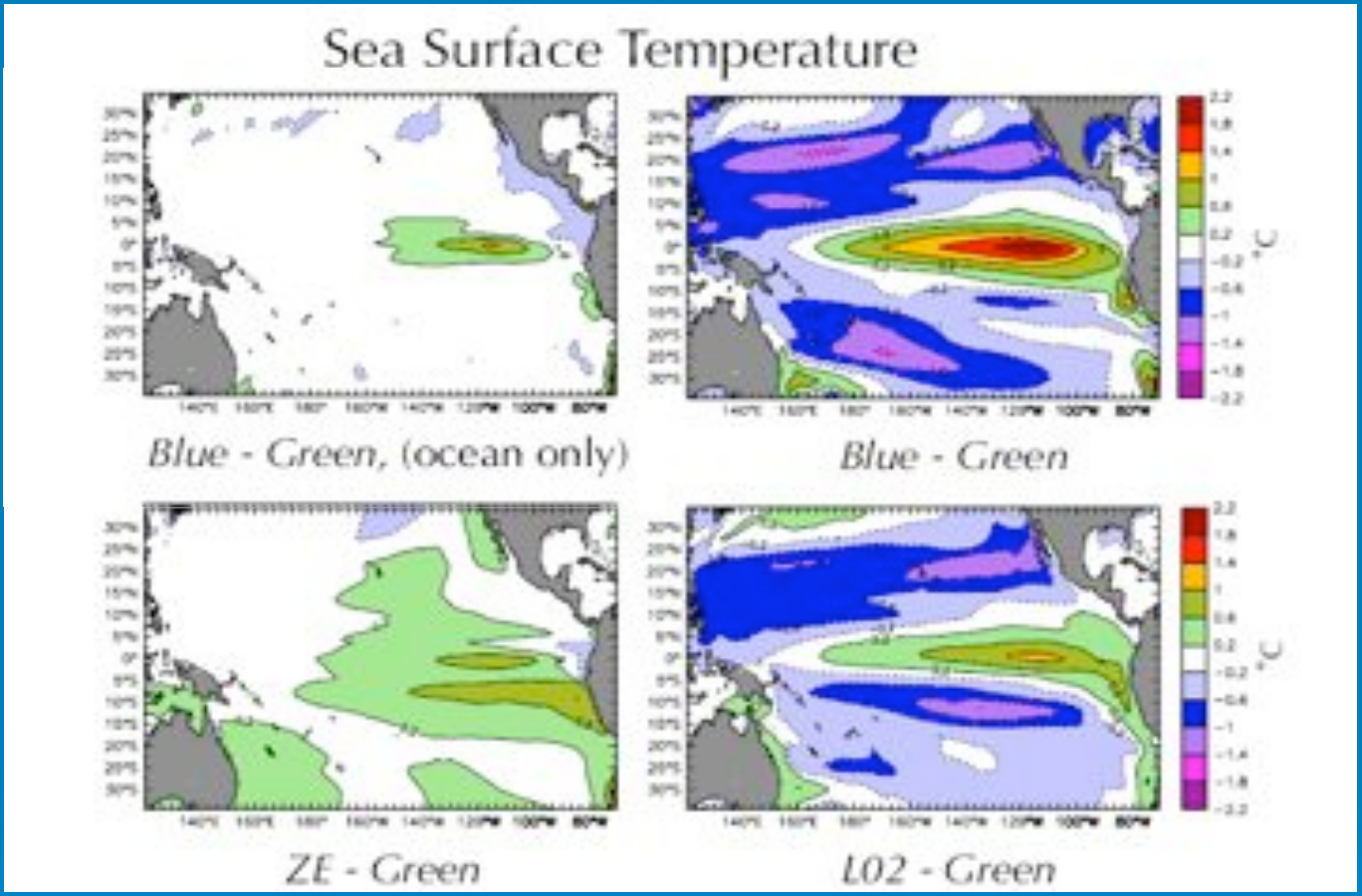
Base state has significant absorption.

Absorption increases along equator, decreases off-equator.

Strategy

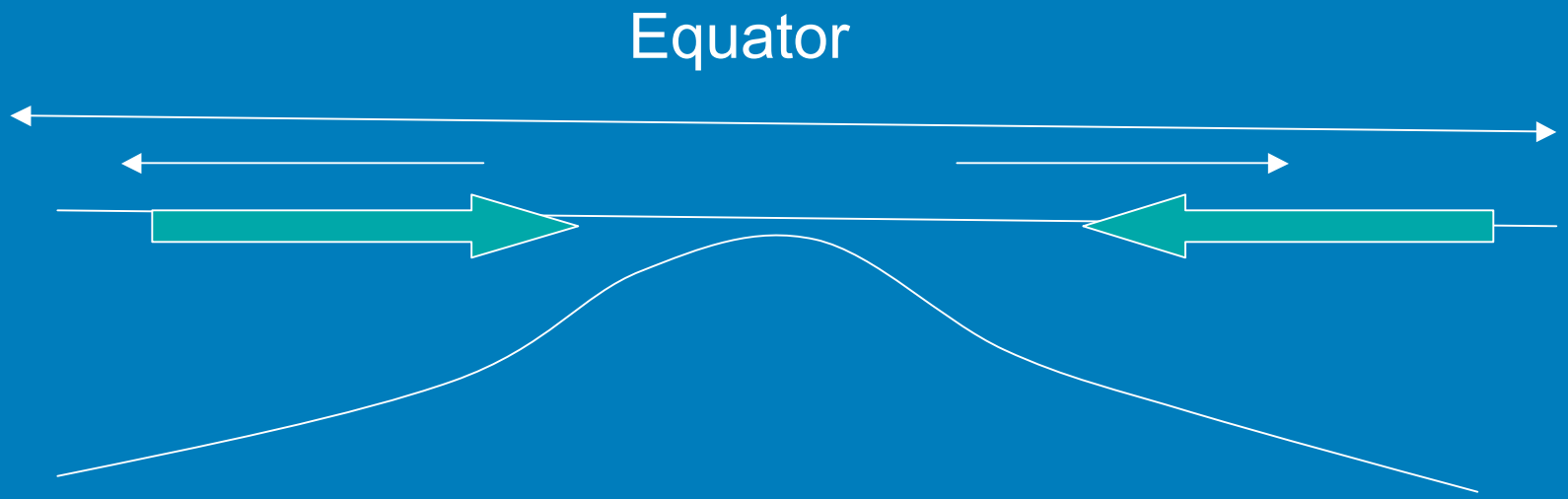
- New model developed for the IPCC Fourth Assessment. (Delworth et al., J. Clim. 2006, Gnanadesikan et al., J. Clim, 2006)
- Use atmospheric, sea ice, land components from IPCC model.
- Use isopycnal layer model for ocean.
- “What if” studies with this coupled climate model.

Impact of removing ocean color on SST



Anderson et al., subm. GRL.

Mechanism #1- local ML deepening



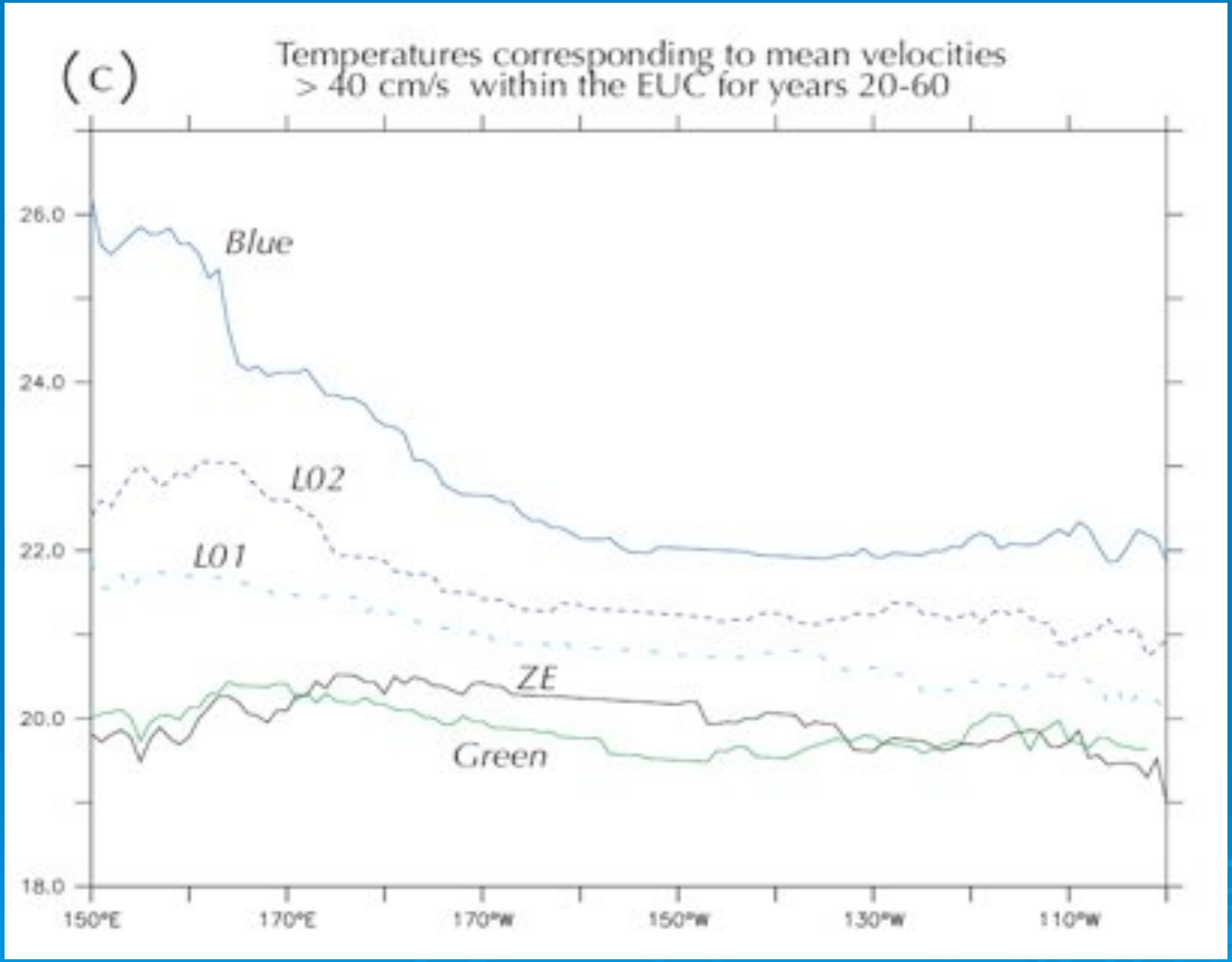
Ekman flow away from equator- independent of mixed layer depth.

Geostrophic flow back towards equator- distributed between mixed layer and upper thermocline.

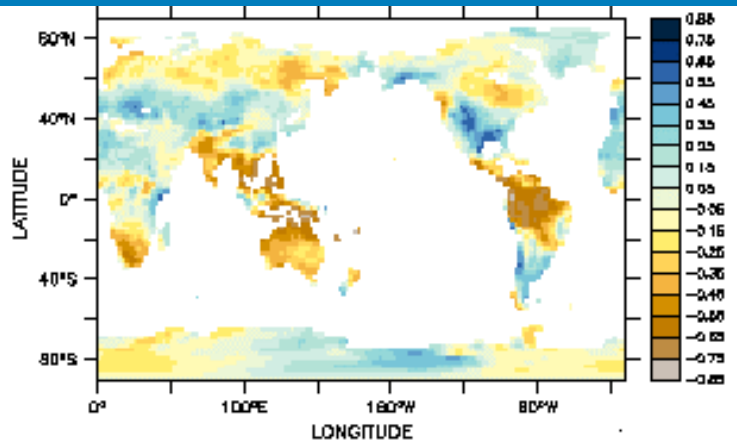
Deeper mixed layers mean less net upwelling.

Anderson et al. (subm.), Sweeney et al., JPO, 2005 (similar results seen by Shell, Manizza).

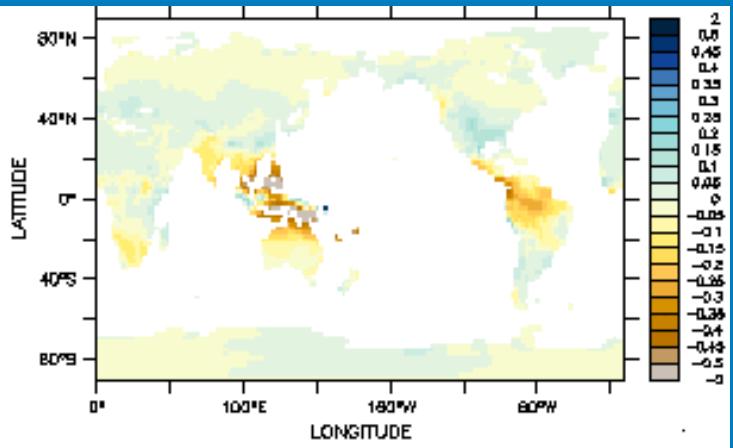
Mechanism #2: Off-equatorial shading



Global impacts-hydrological cycle

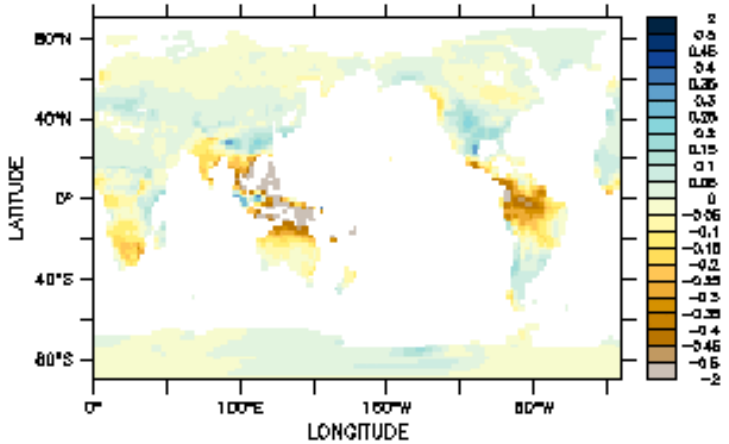


El Nino–Precip Correlation CM2.1HIM



El Nino–Precip Regession CM2.1HIM

TIME : 01–JAN 00:00 to 01–JAN–0101 00:00 NOLEAP



El Nino Precip Anomaly

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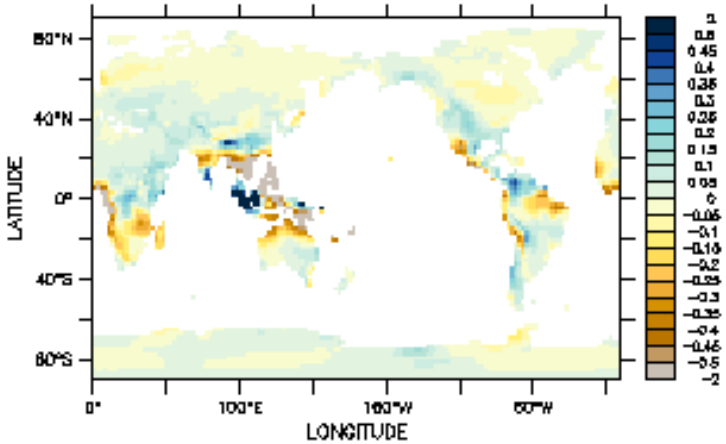
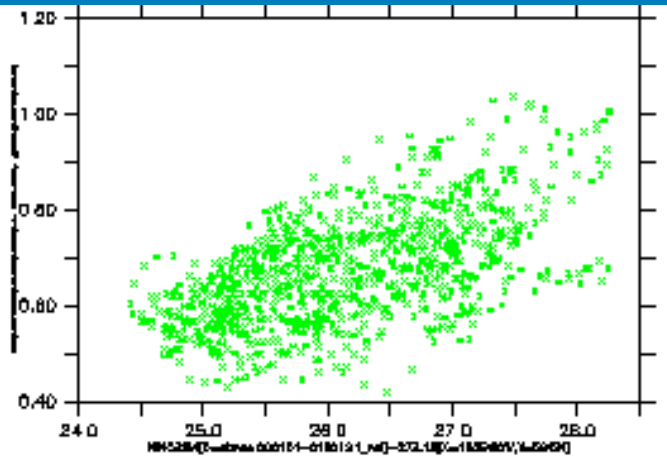
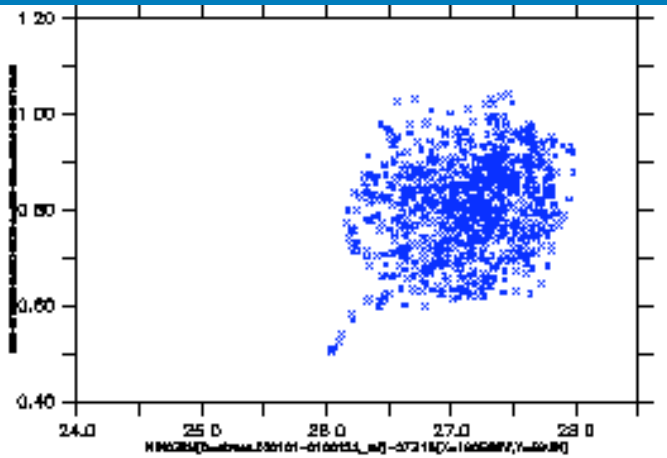


Precip Change: Blue–Green

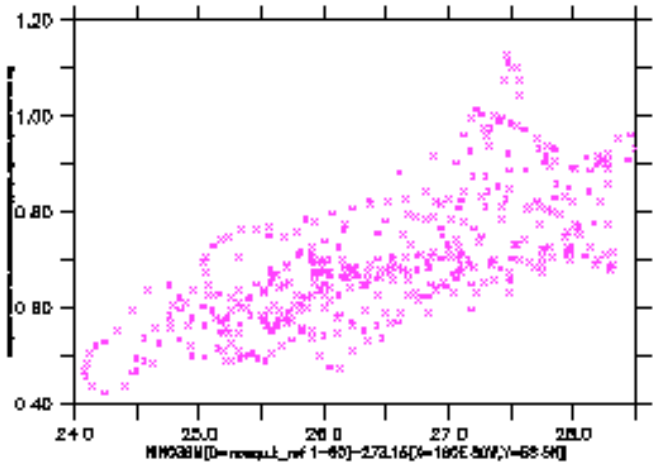
Interannual drought in N. America



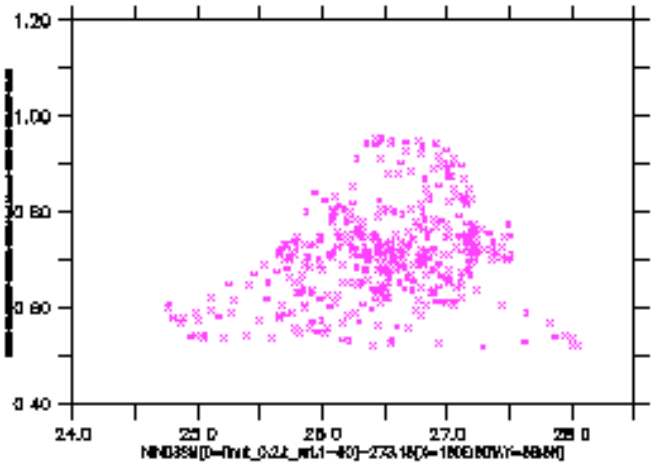
WNAM Precip vs. NINO3: Green



WNAM Precip vs. NINO3: Blue



WNAM Precip vs. NINO3: Noequ



WNAM Precip vs. NINO3: Limit 0.2

Conclusions

- New estimates of particle export are more consistent with a picture in which there is relatively little vertical diffusion in low latitudes.
- Shading of inflowing waters by off-equatorial chlorophyll can have a major impact on the cold tongue.
- Ocean biology can act as a positive feedback on climate variability- depending on where it is.
- Ocean color can affect global climate- but results are regionally dependent.

Issues for this community

- Ocean color matters for climate.
- Clear waters matter!
- Breakdown into different components?
- Should we incorporate in-water radiation models?
- Albedo in clear water?

References

Gnanadesikan, A. et al., Oceanic ventilation and biogeochemical cycling: Understanding the physical mechanisms that produce realistic distributions of tracers and productivity, GBC, GB4010, doi:10.102/2003GB002097, October 20, 2004

Dunne, J.P., R.A. Armstrong, A. Gnanadesikan, J.L. Sarmiento, Empirical and mechanistic models for the particle export ratio, GBC, GB4026, doi:10.1029/ 2004GB002390, December 30, 2005.

Anderson, W.G. et al., Impact of ocean shortwave absorption on the maintenance of the Pacific Cold Tongue, rev. for GRL, 2007.

Dunne, J.P, J.L. Sarmiento and A. Gnanadesikan, 2007, A synthesis of globlal prarticle export from the ocean surface, through the water column and on the sea floor, accepted w/minor rev., Global Biogeochemical Cycles.

http://www.gfdl.noaa.gov/~a1g/bibliography.html